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Energy-Efficient Methods to Maximize Network Lifetime in Wireless Sensor Networks with Adjustable Sensing Ranges

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Abstract— **we study the target coverage problem for wireless sensor networks where every sensor node is capable of adjusting its sensing range. Our aim is to increase the network lifetime by increasing the number of cover sets as many as possible. A cover set is a subset of all sensor nodes that can cover every target node. Instead of keeping all the sensor nodes active at once, network lifetime can be extended by generating a number of cover sets that will monitor the network in turn. We develop two polynomial time algorithms that utilize an efficient contribution formula on circular lists of sensor nodes for building a variety of cover sets. Our proposed algorithms find maximum number of cover sets and consume as low energy as possible for each sensor node. Our simulation results exhibit that the proposed algorithms outperform existing ARSC [1] algorithm in terms of number of cover sets while conserving significant amount of energy among the sensor nodes.**

Keywords- wireless sensor networks; target coverage; adjustable sensing range;

I. Introduction

In recent years wireless sensor networks (WSNs) have gained rapid popularity due to its huge potential into a number of applications such as military systems, biomedical applications, habitat monitoring, seismic monitoring, radiation and nuclear threat detection systems etc. [2]. WSNs are characterized by densely populated small size, low battery power sensor nodes that are usually deployed in remote and difficult to access areas. A sensor node monitors and collects data on certain aspect of the environment and communicates data to a base station. While transmitting data a node can perform activities such as in-network data processing and can act as an intermediate node in case of multi-hop communication. Although, WSNs share many similarities with other network systems, they have a variety of unique challenges and constraints as well. An important concern in designing different protocols and algorithms for WSNs is power scarcity that occurs due to small battery size and limited weight of sensor nodes. As battery recharging or replacement is not possible due to harsh environmental condition, it becomes very significant to conserve energy of the sensor nodes in order to extend the operational lifetime of WSNs. Energy limitation of WSNs is addressed in a number of ways in literature. One way is to keep the idle sensor nodes in low energy sleep mode, while other sensors are kept awake as they are performing some operation [2]. Another approach is to adjust the transmission range so that the sensor nodes only use energy enough for transmitting to a neighboring node [2].

In this paper, we investigate the target coverage problem in energy constrained WSNs. In target coverage problem, N sensor nodes are exploited to observe M target nodes scattered at different positions of a WSN. In such networks, targets can be tracked by selecting a set of sensor nodes instead of using all the sensor nodes. This set is known as cover set. By generating a number of cover sets and assigning responsibility on them to observe network in turn will ultimately increase the lifetime of the network. At a given point of time, only the sensor nodes of a particular cover set will be active while the other nodes will remain in sleep mode. We consider a WSN where each sensor node is associated with a number of adjustable sensing ranges. By selecting different sensing ranges, each sensor node is capable of monitoring different number of targets. Generating the maximum number of cover sets in such network has been proved to be an NP-complete problem in [1]. Thus we propose two polynomial time heuristic algorithms for addressing the target coverage problem in such networks. The problem is formulated in the next section.

A. Problem Formulation

A *Wireless Sensor Network* is represented by a unit disk graph $G = (V, E)$ where $V = \{S \cup T\}$ is a set of nodes and $E \subseteq V \times V$ is a set of communication links. $S = \{s_1, s_2, \ldots, s_N\}$ represents a collection of N sensor nodes that are deployed randomly to monitor a set of target nodes $T = \{t_1, t_2, \ldots., t_{M.}\}$. Each sensor node $s_i \epsilon S$, can operate into a number of sensing ranges $r_1, r_2, \ldots, r_p$ where each r_k consumes energy e_k, $1 \leq k \leq P$. The initial energy of each sensor node is E. A sensing node $s_j \epsilon S$ can cover a target $t_i \epsilon T$ using sensing range r_k if the euclidean distance $dist_{ij}$ is less than or equal to r_k, $1 \leq i \leq N$, $1 \leq j \leq M$, $1 \leq k \leq P$. Our purpose is to extend the network lifetime by scheduling sensor nodes to continuously monitor M targets in turn. For this reason a collection of *Cover Sets* $C = \{C_i\}$, $1 \leq i \leq K$ is constructed. A cover set C_i is a subset of S that can monitor all the target nodes. Sensor nodes belonging to a particular C_i will be active for a fixed time interval while the remaining nodes are kept in sleep mode and then another C_j will take the responsibility of monitoring the WSN. Thus increasing the value of K will extend the operational lifetime of a WSN. As a sensor node s_i can adjust its sensing range up to P levels, it is possible to conserve energy by setting the minimum possible sensing range for each $s_i \in C_j$, $C_j \in C$. Thus the problem we address is: Given $T = \{t_1, t_2, \ldots, t_M\}$ and $S = \{s_1, s_2, \ldots, s_N\}$ with P adjustable sensing ranges, our aim is to find a collection C of set covers of size K with minimum possible assignment of sensing ranges such that $K \geq K'$ for all possible collection of cover sets of size K' and $\sum_{i=1}^{K} E_i \leqslant \sum_{i=1}^{K'} (E_i)$ where E_i is the energy consumed by a cover set $C_i \in C$.

B. Our Contributions

In this paper, we explore the target coverage problem of WSNs with adjustable sensing ranges. We propose two polynomial time algorithms: Adjustable Range Set Cover with pushback (ARSC_P) and Adjustable Range Set Cover with selective pushback (ARSC_SP). Both algorithms generate moderate number of cover sets and save energy as it is possible to choose a smaller sensing range over the larger ones. By utilizing an improved contribution formula the selection process of sensor nodes for cover sets gets simplified that ultimately improves the energy efficiency of WSNs. We compare the performance of our proposed algorithms with existing ARSC [1] algorithm. The experimental results show that our algorithm ARSC_SP exhibits best performance in generating the cover sets and both algorithm preserve significant amount of energy among the sensor nodes.

The rest of the paper is organized as follows: In section II we present a study on the target coverage problem in WSNs. We present our algorithms in Section III. In section IV we discuss the experimental results. Finally, we explain the findings of our research and future extensions of our work in section V.

II. Related Work

Target coverage problem of WSNs is intensively studied in literature. Cardei et el. explored the problem of maximizing network lifetime in [3] and modeled the target coverage problem as Maximum Set Cover (MSC) problem. The MSC problem organizes sensor nodes into a number of sets and finds maximal possible number of sets. The authors proved that MSC problem is NP-Complete and proposed two efficient heuristic algorithms to compute the cover sets using linear programming and greedy approach, respectively. In the greedy heuristic, a critical target is selected in each step and a sensor node that monitors that critical target as well as the maximum number of other targets is included in the cover set. The authors of [4] identified that residual energy of sensor nodes is not considered during the construction of set cover. As a result a sensor node covering maximum number of targets is selected repeatedly in every cover set and this node quickly exhausts energy. The authors proposed a new energy-efficient algorithm by taking into account the overlapping target nodes and the residual energy of sensor nodes. In [5], Pyun et el. proposed a sensor scheduling algorithm for Multiple Target Coverage (MTC) problem. They considered periodic sensing applications where a sensor node senses and collects data from targets in turn. Their proposed algorithm calculates the transmitting energy of a sensor node as the summation of energy consumed for every target node it covers and also assigns a responsible sensor for each overlapped target by making the other redundant sensors free from monitoring the same target node. In [6] Berman et el. suggested an efficient data structure to represent the monitored area with at most n^2 points guaranteeing the full coverage. They have provided some effective centralized sensor monitoring algorithms to maximize the network lifetime. Partially covered area is also monitored in these algorithms and several distributed protocols are introduced with trade-off between communication and monitoring power consumption. Cardei et el. addressed the Connected Set Cover (CSC) problem in [7] with the objective of maximizing network lifetime while maintaining the base station connectivity of each active sensor node. They proposed an integer programming based solution, a centralized greedy solution and finally a distributed and localized solution. In the greedy solution, the authors first constructed a cover set and then generated a BFS tree with the base station as root. The BFS tree is pruned so that it contains paths only to sensor nodes in the cover set. Nodes in the BFS tree that are not in the cover set will act as relay nodes.

We compare the results of our algorithms with an existing algorithm in literature: Adjustable Range Set Cover (ARSC) [1]. The authors of [1] considered the target coverage problem for WSNs consist of sensor nodes with multiple sensing ranges. They proposed a centralized greedy algorithm known as ARSC that ensures coverage requirement by producing a number of set covers where each member of a set cover uses minimum sensing range. For each sensor $s_i \in S$, a contribution value $\Delta B_{ip} = \Delta T_{ip} / \Delta e_p$ is determined. ΔT_{ip} indicates the increase in the number of uncovered nodes if the sensing range is increased from r_q to r_p and is calculated as $\Delta T_{ip} = T_{ip} - T_{iq}$ where T_{ip} and T_{iq} are the set of target nodes covered by s_i at sensing range r_p and r_q, respectively. Δe_p is the increase in energy if the sensing range is updated from r_q to r_p and is calculated as $\Delta e_p = e_p - e_q$ where e_p and e_q are the energy consumed by s_i at sensing range r_p and r_q, respectively. A sensor node s_i with the highest ΔB_{ip} is selected to participate in a cover set. The sensing range of s_i is updated to r_p and target nodes covered by s_i for sensing range r_p are removed from other sensor nodes coverage sets. Cerulli et el. presented an Adjustable Ranges Greedy (AR-Greedy) algorithm in [8] that builds one cover set at a time and assigns appropriate activation times within the limit to keep the solution feasible. Each cover set starting from an empty set, is gradually extended and iteratively completed by including all critical targets which have not been covered yet. Dual heuristic based distributed algorithm (DHD-CS) has been introduced in [9]. Here each sensor node has information about its neighbor nodes. It starts by setting the sensing range

TABLE I. NOTATION USED FOR ALGORITHMS

S	Set of sensor nodes $\{s_1, s_2, \ldots s_N\}$
T	Set of target nodes $\{t_1, t_2, \ldots, t_M\}$
R	Set of sensing ranges $\{r_1, r_2, \ldots, r_p\}$
E	Initial energy of a sensor node
e_k	Energy consumed by sensing range r_k
L_i	$\{s_jr_k \mid s_j$ covers t_i with sensing range $r_k\}$
τ_{jk}	Number of targets covered by s_jr_k
E_{res_j}	Residual energy of a sensor node s_j.
Φ_e	Energy ratio formulated as E_{res_j} / e_k.
B_{jk}	Contribution of s_jr_k defined as $\tau_{jk} \times \Phi_e$.
T_A	List of uncovered target nodes

of each sensor to its maximum value. If the sensor detects no targets within its r_{max} then it goes to sleep mode. Otherwise node starts a priority timer based on its utility function. The authors of [10] addressed the problem of maximizing the network lifetime while maintaining the network connectivity. They studied the relationship between target coverage and network connectivity and established a generic condition to achieve both and finally proposed a distributed and localized algorithm to construct cover sets while maintaining connectivity among the active sensor nodes. According to the algorithm, a connected dominated set is constructed that is pruned to eliminate redundant sensor nodes and then both dominator and dominatee nodes are participated to cover target nodes by adjusting their sensing ranges. In [11] the authors focused on maximizing the network lifetime directly rather than increasing the number of cover sets. They devised a mathematical model of the problem using a linear program comprising of exponential number of variables and solved it using an existing approximation algorithm proposed by Garg-Konemann [12]. Their model works with non-uniform batteries that allow smooth sensing range variations and also facilitates assigning fractional time to each cover sets. The authors claimed that their approach achieved four times performance improvement as compared to ARSC [1] proposed by M. Cardei. In [13], the authors studied energy-efficient coverage problems present in literature, their coverage formulations and the assumptions made along with an overview of the proposed solutions. The coverage formulations vary depending on a number of issues like deployment methods, network connectivity and energy consumption.

III. PROPOSED ALGORITHMS

In this section we present two polynomial time algorithms to address the target coverage problem in WSNs consist of sensor nodes with adjustable sensing ranges. Some basic notations used to explain the algorithms are presented in Table I.

A. Adjustable Range Set Cover with pushback (ARSC_P) Algorithm

This algorithm creates for each target $t_i \in T$, a list L_i of Sensor-Range (SR) combinations covering t_i. A SR combination denoted by s_jr_k signifies that sensor s_j covers a specific target with sensing range r_k. Each L_i is represented as a circular list. If a t_i is covered by r_k of a sensor s_j, all the ranges of s_j greater than k are eliminated from L_i. For example, if a target t_1 is covered by a sensor s_1 with sensing range r_1 all the greater ranges r_2, r_3, r_4… etc, are omitted from L_1 even though they cover t_1. Each L_i is sorted in ascending order of the contribution value B_{jk} of its elements. ARSC_P chooses among the elements with highest value of each L_i depending on 3 criteria:

Criterion-1: SR combination with highest B_{jk} value

Criterion-2: *SR combination with highest τ_{jk} value*

Criterion-3: *SR combination with the lower e_k value*

After selecting a SR combination, ARSC_P checks if it covers any other targets t_j and skip L_j in subsequent considerations for constructing a cover set. SR combinations are repeatedly selected based on the above mentioned criteria until all targets are covered. Residual energy of each sensor node is updated at this point and the selected SR combinations for the current cover set are pushed back to the corresponding lists. The whole process is repeated to create another cover set until one of the L_i becomes empty. A SR combination is omitted from the L_i if its required energy exceeds the remaining energy.

B. Adjustable Range Set Cover with selective pushback (ARSC_SP) Algorithm

This algorithm is similar to our ARSC_P algorithm and differs only in the way push back operation is performed. This algorithm utilizes a selection procedure that determines a particular SR combination to be pushed back. A new selection measure *Energy Ratio* denoted by Φ_e is introduced that is a ratio of E_{res_j} to e_k for a particular s_jr_k. This value indicates the future usability of a specific s_jr_k. The more is its value, the more is its probability of using in a cover set in future. ARSC_SP pushes back the SR combination with minimum Φ_e. The progression continues until one of the lists gets empty. The aim of using selective pushback operation is to ensure a better residual energy distribution for sensor nodes.

The pseudo code for ARSC_SP is shown in Algorithm 1. We present only the pseudo code of ARSC_SP as the pseudo code for ARSC_P is almost identical except ARSC_SP is augmented with a selection procedure. The time complexity of both algorithm is $O\ (iM \log_2 N + iM^2)$ where M is the number of targets, N is the number of sensors, i is the number of cover sets generated and i is upper-bounded by $N \times (E/e_1)$ that corresponds to the case when all the targets are covered by all sensors with range r_1.

Fig. 1 shows a WSN consists of 4 sensor nodes $\{s_1, s_2, s_3, s_4\}$ and 3 target nodes $\{t_1, t_2, t_3\}$. Each sensor has 2 adjustable

Algorithm 1 Adjustable Range Set Covers with selective push back

INPUT:
S: $\{s_1, s_2, \ldots, s_N\}$
T: $\{t_1, t_2, \ldots, t_M\}$
E: *Initial Energy of each* s_j, $1 \le j \le N$
R: $\{r_1, r_2, \ldots, r_p\}$

OUTPUT: A collection of cover sets $C = \{C_i\}$, $1 \le i \le K$

for each target $t_i \in T$ **do**
  for each sensor $s_j \in S$ **do**
    Calculate $dist_{ij}$ from t_i to s_j
    for each range $r_k \in R$ **do**
      if $dist_{ij} \le r_k$ **then**
        Calculate τ_{jk} and Φ_e
        Calculate $B_{jk} := \tau_{jk} \times \Phi_e$
        Push $s_j r_k$ into L_i
      end if
    end for
  end for
end for
Sort L_i in ascending order of B_{jk}
$q := 0$
while any L_i is not empty **do**
  for each L_i **do**
    Remove top $s_j r_k \in L_i$ with $E_{res_j} < e_k$
  end for
  Sort all L_i on top element $s_j r_k$ value of B_{jk}, τ_{jk} and e_k
  q ++
  min_sensor: $=0$
  min_energy: $=E$
  min_list: $=0$
  T_A: $=T$
  while T_A is not empty **do**
    Select the top element $s_j r_k \in L_i$ with maximum value
    Insert into C_q
    Update the sensing range of s_j to r_k
    for each t_r covered by $s_j r_k$ **do**
      Mark L_r: = *USED*
    end for
    Update E_{res_j} of s_j
    if $E_{res_j} <$ *min_energy* **then**
      min_sensor: $=s_j$
      min_range: $=r_k$
      min_list: $=i$
    end if
  end while
  Push back *min_sensor* with *min_range* into L_i
end while

Algorithm 1. Pseudo code for ARSC_SP for Constructing Cover Sets

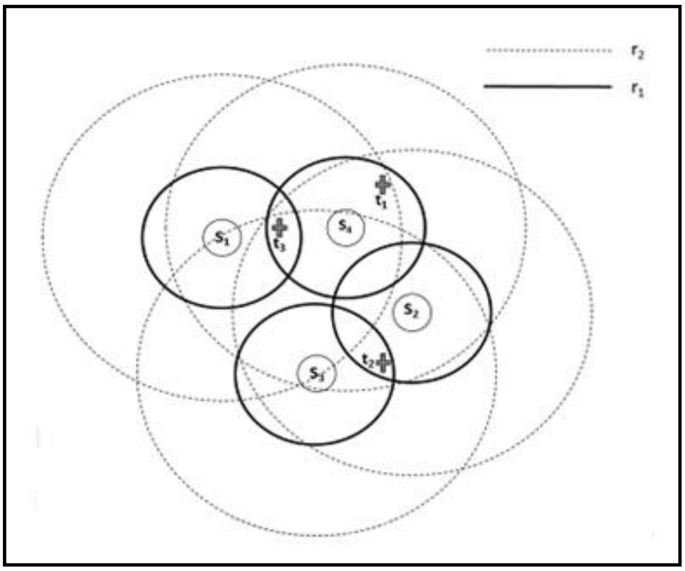

Figure 1. WSN with 4 sensors and 3 targets

sensing ranges referred as r_1 and r_2 where $r_1 < r_2$. We assume the sensing area of each node is a disk centered at the sensor node where the radius of the disk is equal to its corresponding range. In the Fig. 1, r_1 is shown with bold solid line and r_2 with the light dotted line. If t_1 is covered by r_1 of s_1 then we will denote the coverage relationship as $t_1 \Rightarrow s_1 r_1$. Thus the coverage relationships as depicted in Fig. 1 are:

$t_1 \Rightarrow s_1r_2, s_2r_2, s_4r_1, s_4r_2$
$t_2 \Rightarrow s_2r_1, s_2r_2, s_3r_1, s_3r_2, s_4r_2$
$t_3 \Rightarrow s_1r_1, s_1r_2, s_4r_1, s_4r_2, s_3r_2$

We consider the initial energy of sensor node E=2 unit. Energy consumed for range r_1 is $e_1 = 0.5$ unit and for r_2 is $e_2 = 1.0$ unit. We describe the working procedure of ARSC_SP on the WSN illustrated in Fig. 1. Here we explain only the first cover set formation using ARSC_SP. The initial lists generated by ARSC_SP are shown in Fig. 2. Here, s_4r_1 is chosen as it has the highest contribution value and it covers both t_1 and t_3. As shown in Fig. 3, target t_2 is covered by the combination s_4r_2. So the first cover set formed is $\{s_4r_1, s_4r_2\}$ that finally upgrades as $\{s_4r_2\}$.

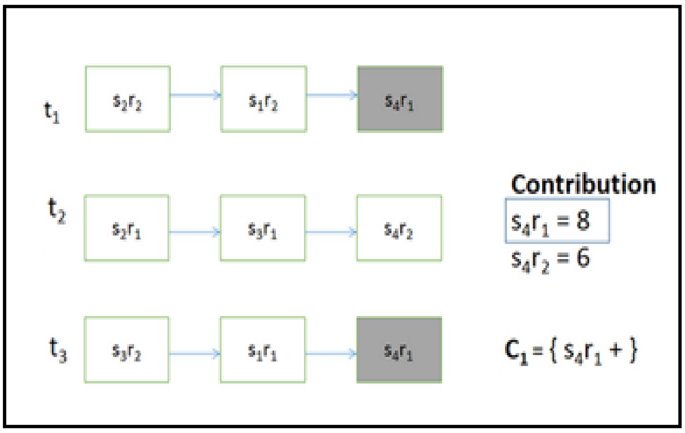

Figure 2. Construction of cover set with ARSC_SP

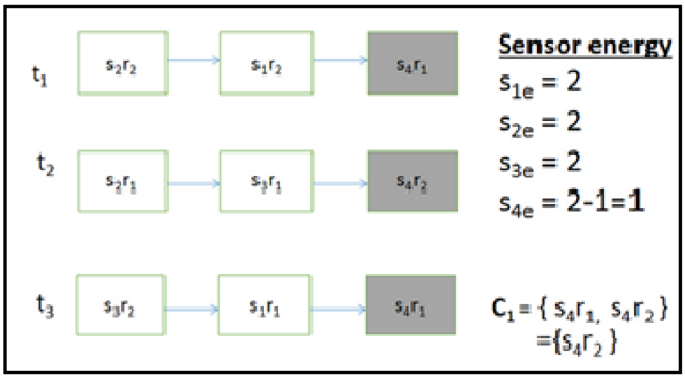

Figure 3. Construction of cover set with ARSC_SP

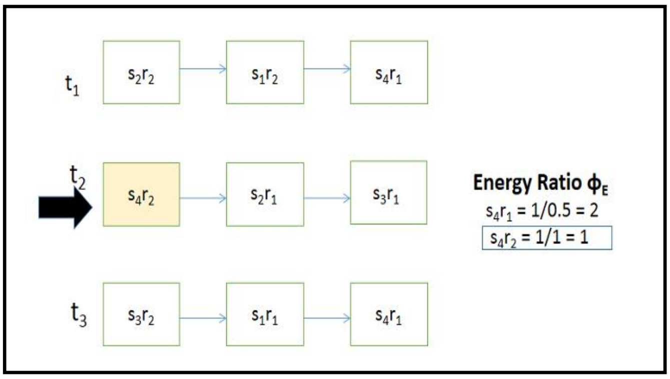

Figure 4. Construction of cover set with ARSC_SP

Residual energy of s_4 is also updated. After construction of cover set, an element with the lowest Φ_e value is pushed at the end of the list. As shown in Fig. 4, s_4r_2 is pushed back into L_2. In a similar fashion all the other cover sets are generated. This process runs until one of the target lists becomes empty. The cover sets generated by ARSC_SP on the WSN in Fig. 1, are $\{s_4r_2\}$, $\{s_4r_1, s_3r_1\}$, $\{s_1r_2, s_3r_1\}$, $\{s_2r_2, s_1r_1\}$, $\{s_4r_1, s_3r_1\}$ and $\{s_4r_1, s_3r_1\}$. Thus the network lifetime is 6. Residual energy of each sensor s_1 = 0, s_2 = 0, s_3 = 0.5 and s_4 = 0 unit.

IV. SIMULATION RESULTS

We conducted extensive simulations in order to evaluate the performance of our proposed algorithms and compared the results with the existing ARSC [1] algorithm. The main performance metrics used were the network lifetime measured by the number of cover sets and residual energy distribution of sensor nodes.

In all our simulations, we used Java Platform (JDK 7). We generated networks by deploying the sensor and the target nodes randomly in a geographic area of 100m × 100m. The number of sensor nodes is denoted by N and we considered networks with 20, 30, 40, 50, 60 and 70 nodes. We used 10 target nodes in all our simulations and the number of target nodes is denoted by M.

For each sensor node, we specified P sensing ranges r_1, r_2,...., r_P and the values of P were chosen between 2 to 4. As sensing range we selected between 30*m* to 60*m* with an increment of 10. The initial energy E of each sensor node was set to 10. For each value of N and M = 10, we generated 100 networks and the results are averaged over 100 networks. We used the linear energy consumption model described in [1] to calculate e_i for each r_i, $1 \le i \le P$ where $e_i = c \times r_i$ and c is a constant defined as $E/2 \times (\sum_{i=1}^{P} r_i)$. The results are presented in the following sections.

A. Performance Analysis in terms of Network Lifetime

The network lifetime of a WSN will be extended with the increase of cover sets because, the cover sets monitor the network in turn until the energy of sensor nodes exhausts.

We compare the network lifetime computed by ARSC, ARSC_P and ARSC_SP for a variety of sensing ranges. We consider WSNs with 20 to 70 sensor nodes and 10 target nodes. As shown in Fig. 5, for $P=2$, *ARSC* algorithm gives better network lifetime as compared to the proposed algorithms. *ARSC_P* and *ARSC_SP* exhibit almost similar performance. We consider r_1 =30*m* and r_2 =60*m*.

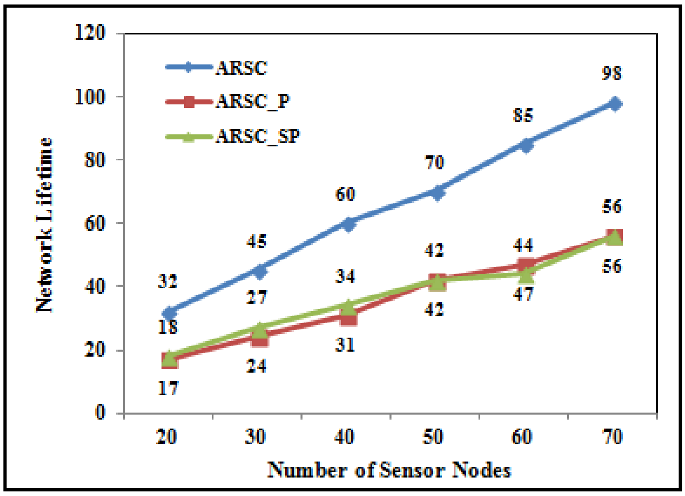

Figure 5. Network Lifetime for P=2 and M=10

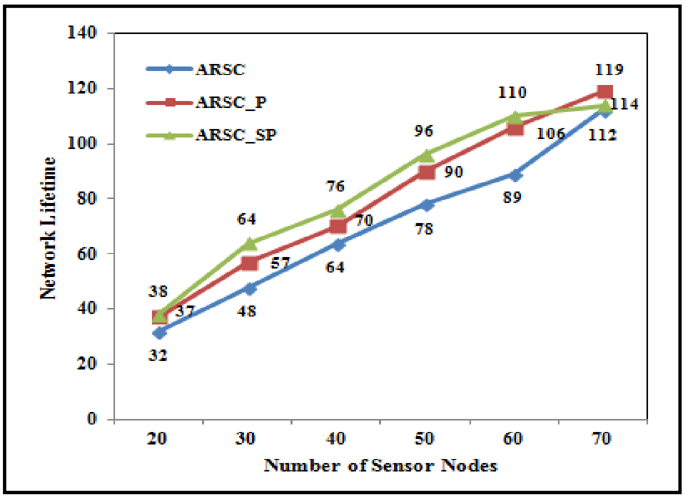

Figure 6. Network Lifetime for P=3 and M=10

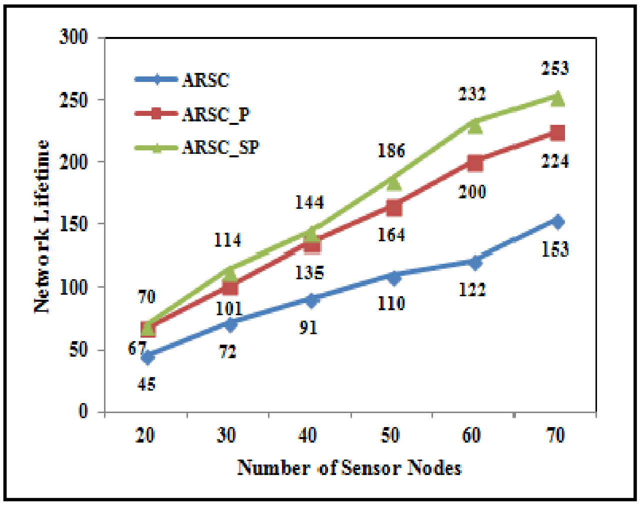

Figure 7. Network Lifetime for *P*=4 and *M*=10

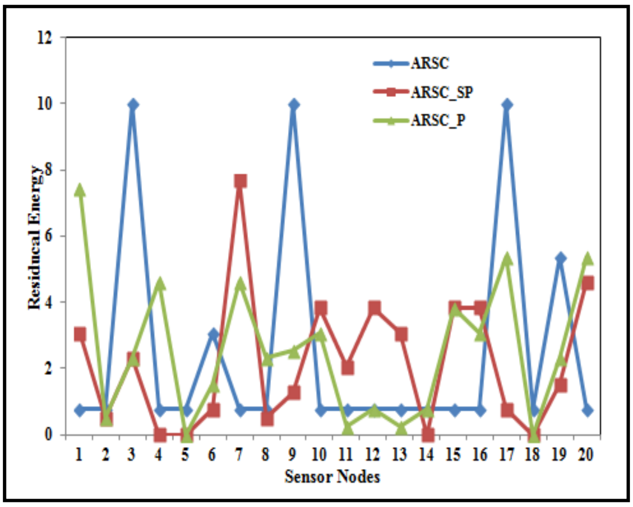

Figure 8. Residual Energy Distribution for *P* = 3, *M* = 10 and *N* = 20

The performance of the proposed algorithms has improved for increasing values of *P*. For *P = 3*, *ARSC_SP* gives better network lifetime than that of *ARSC_P* and both of them gives better result than *ARSC*. *ARSC_SP* shows more efficiency than *ARSC_P* for 20 to 60 sensor nodes. Here, sensing ranges r_1 = 30*m*, r_2 = 40*m* and r_3 = 60*m* are considered. As shown in Fig. 6, *ARSC_SP* achieves a maximum improvement of 33.33% over *ARSC* and 12.28% over *ARSC_P* at *N*=30. *ARSC_P* generates 19.10% more cover sets as compared to that of *ARSC* algorithm at *N*=30.

Both *ARSC_SP* and *ARSC_P* are clearly ahead of *ARSC* and *ARSC_SP* gives the best result among the three algorithms for *P=4* and the performance of algorithms are illustrated in Fig. 7. We consider r_1 = 30*m*, r_2 = 40*m*, r_3 = 50*m* and r_4 = 60*m*. As shown in Fig. 7, *ARSC_SP* generates about 90.16% and 16% more cover sets as compared to that of *ARSC* and *ARSC_P* algorithm at *N* = 60, respectively. *ARSC_P* attains an improvement of 63.96% over *ARSC* at the same value of *N*.

We can conclude that network lifetime produced by our algorithms is longer than that of *ARSC*. This happens because the number of SR combinations increases as we increase the number of sensing ranges. As our algorithms always select sensor node with greatest contribution value, it gives us better choice in selecting cover sets that results in an improved network lifetime. In case the contribution values are equal, we check two extra criteria instead of arbitrarily breaking the tie. These checks give us better choice in producing cover sets and also better network lifetime than *ARSC*. Although our algorithms do not exhibit good performance for *P=2* but network lifetime increases as the value of *P* is increased. For *P*=2, we used r_1= 30*m* and r_2 = 60*m*, while for *P*=3 and 4, we utilized r_1 = 30*m*, r_2 = 40m, r_3 = 50*m* and r_4 = 60m. By assigning intermediate values of 40*m* and 50*m* between 30*m* and 60*m*, most of the targets are covered by 40*m* or 50*m* instead of using 60*m*. As we can use less energy for 40*m* and 50*m* in case of *P* = 3 and 4, it saves energy that ultimately increases the number of cover sets.

B. *Performance analysis in terms of Energy Distribution*

Our second concern in performance measurement is to ensure a balanced distribution of residual energy among the sensor nodes. Fair expenditure of energy prevents many sensor nodes from quick energy exhaustion while other nodes may have almost full energy unused and this has great impact in increasing the number of cover set that is evident from our experimental results. Our algorithms can conserve energy of more sensor nodes as compared to ARSC.

For each of the algorithms, we calculated the residual energy of every node when 10 targets are monitored by 20 sensor nodes using 3 and 4 sensing ranges, respectively. Fig. 8 shows the residual energy of every sensors for *P* = 3, *M* = 10, *N* = 20. As depicted in Fig. 8, in case of ARSC algorithm, most of the sensor nodes exhaust energy while some nodes preserve the initial energy *E* = 10. Our algorithms assure uniform dissipation of energy among the sensor nodes and carry more energy for each sensor as compared to *ARSC*. Fig. 9 illustrates the distribution of residual energy of each sensor node for

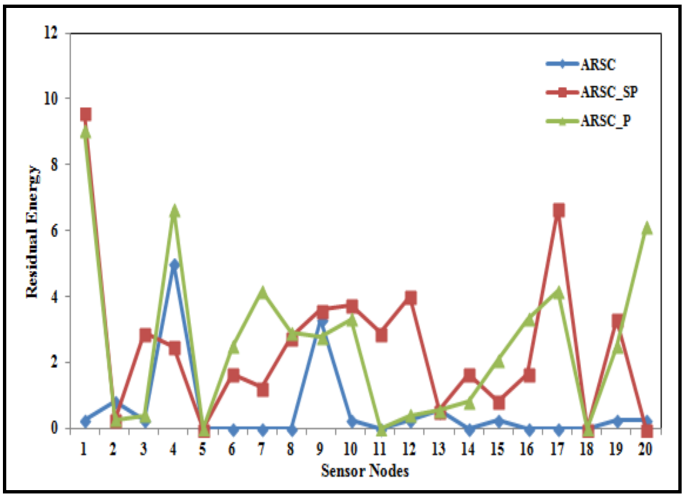

Figure 9. Residual Energy Distribution for *P* = 4, *M* = 10 and *N* = 20

ARSC, *ARSC_P* and *ARSC_SP* when $P = 4$. The graph clarifies our algorithm conserves more energy for sensor nodes as compared to that of *ARSC*.

In *ARSC* the contribution value does not depend on the residual energy of a sensor node. This means that in [1], the algorithm uses the same cover set until one of its sensor nodes is exhausted completely. Our algorithms generate a variety of cover sets instead of repeated cover sets. The selected elements are pushed back in order to create different cover sets each time that doesn't exhaust a sensor in quick succession. The energy preservation among the sensor nodes is also improved as our algorithms always try to include sensors with minimum possible sensing range into a cover set.

V. Conclusion

In this paper we worked on constructing energy efficient target coverage models for WSNs with adjustable sensing ranges. We developed two polynomial time greedy algorithms using certain pushback methods to generate cover sets. These algorithms use circular lists of sensor nodes along with efficient contribution formula that help in building different cover sets as the number of sensing ranges is increased. Simulation results proves that our algorithms are better than existing ARSC algorithm in terms of total number of cover sets and establish uniform expenditure of energy among the sensor nodes.

In future we are interested to refine the contribution formula to take into consideration the critical targets. Data aggregation and routing are also important factors for conserving energy. We can accumulate these two cases with our existing algorithms and increase the versatility of our approaches.

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